

Lunar Reconnaissance Orbiter: (LROC)

Audience

Grades 5-9

Time Recommended

2-4 Hours

AAAS STANDARDS

- 1B/1: Scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.
- 3A/M2: Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

NSES STANDARDS

Content Standard A (5-8): Abilities necessary to do scientific inquiry:

- a. Identify questions that can be answered through scientific investigations.
- c. Use appropriate tools to gather, analyze and interpret data.
- d. Develop descriptions and explanations using evidence.
- e. Think critically and logically to make relationships between evidence and explanations.

Content Standard D (5-8): Earth and Space Science; Earth's History:

- a. The Earth processes we see today, including erosion, movement of lithospheric composition, are similar to those that occurred in the past.

Content Standard E (5-8): Science and Technology:

- b. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

MATERIALS

- Lunar Image Analysis Student Data Log
- Lunar Image Analysis Observation Sheets
- Lunar Image Analysis Topic Selection Sheet
- Lunar Reconnaissance Orbiter Camera (LROC) Wide-Angle Camera (WAC) Lunar Orbiter
- Laser Altimeter (LOLA) Topographic Map
- Access to JMARS for Moon
<http://jmars.asu.edu/download-jmoon>

Question Moon: An Introduction to the Process of Science

Learning Objectives:

- Generate a big picture question related to the Moon.
- Generate hypotheses related to lunar geology.
- Generate a research question related to lunar geology.

Overview: In this activity, students step into the shoes of real planetary scientists and experience one of the first steps in the process of science—developing hypotheses and testable research questions. Students will be tasked with using the topic identified in the Lunar Image Analysis activity to establish hypotheses and a question about the surface of the Moon. The purpose of this lesson is for students to use a critical thinking, collaborative approach to scientific research within the field of planetary geology.

Preparation:

1. All science begins with a question or a hypothesis. Keep in mind that it is a natural part of science to refine or even change your question as your research progresses. The process of science continues with designing an experiment to answer that question and test your hypotheses. For this activity, the focus is on generating a high-quality research question and hypothesis.
2. Students will need the Lunar Image Analysis materials for this lesson and should be grouped in small groups (approximately 3-4) for brainstorming and development of hypotheses and questions.

Background Information:

STUDENT SHEET #1:

The intention of this sheet is to help students understand that scientists do not use a contrived process in developing a question and hypothesis, but instead they make observations that guide their hypotheses and their questions. Examples have been provided for students to work with and to establish a model. It would be helpful to have conversations with the students about these examples to ensure they understand the difference between the big picture question, hypothesis, and research question.

STUDENT SHEET #2:

These sheets are provided to give students a guide for their initial questioning. The prompts provided are not the only prompts students can use, but these cover the major types of questions students will ask while making their

observations. These big picture questions are important questions, but are not research questions. These are very broad questions, which require a significant amount of research to answer. In this case, the students will be investigating one small aspect of the their big picture question. Give students the opportunity to work together in groups for brainstorming. As a team, the students will need to make calculated decisions, so debate and collaboration will be extremely important.

STUDENT SHEET #3:

In this sheet, students will begin developing explanations for their big picture questions. These will eventually be hypotheses, but for now, they will most likely just be ideas. These will be critical in developing high quality research questions and hypotheses. Students will need the opportunity to work in JMARS for Moon (<http://jmars.asu.edu/download-jmoon>) in order to check that these explanations have measurable attributes and data is currently available.

STUDENT SHEET #4:

Students will use the explanations they have established in the previous sheet to create research questions. These questions will need to be testable and the students will need to establish what exactly will be measured in the experiment (to learn if their explanation is true). A list of possible variables (in a simplified form) have been provided in the lesson, but research questions are not limited to these variables— these are simply a guide to get students moving in the right direction. As a class, they will need to make decisions together, so debate and collaboration will be extremely important. See the assessment section for the rationale on given evaluation criteria.

STUDENT SHEET #5:

Now that students have a research question, they can write a formal hypothesis. The “if...then...” statement has been provided as a guide, but is not 100% true in all cases. There is no need to use it if it doesn’t make sense. By the end of this sheet, students should have a final research question and a matching, testable hypothesis. As a class, they will need to make decisions together, so debate and collaboration will be extremely important.

Procedure:

1. See worksheets for guidance.
2. Provide a set of worksheets for each student

QUESTION MOON

An Introduction the Process of Science

Objective:

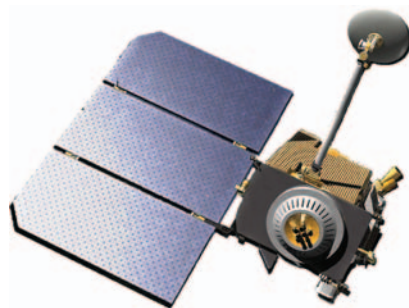
Create a question and hypothesis about the Moon that can be answered using images taken from orbit.

Student Introduction:

All science begins with a question or an hypothesis. Some people refer to this as the “scientific method”. The scientific method starts from questions or hypotheses we create based on our curiosity. We become curious about scientific observations we make. Professional scientists have questions about the Moon they want to answer because they are curious, and so you will begin by investigating images from Earth’s nearest neighbor. Keep in mind it is a natural part of science to refine or even change your question as you research. The process of science continues with designing an experiment to answer that question and test your hypotheses.

Your goals through this lesson are:

- Follow your curiosity about the Moon and create research questions and hypotheses
- Evaluate your questions, making sure you have met the criteria for a scientific question
- Realize there are three different types of questions for research based on the branch of science you are conducting your research in.
- Realize that it’s understandable to have “big picture” questions, but scientists (including you) need a specific focus or question to study.
- Recongnize that scientists contribute to a greater understanding of the Moon through detailed research.



In 2009, NASA returned to the Moon by sending a robotic scout called the Lunar Reconnaissance Orbiter (LRO) to gather crucial data on the lunar environment. During its orbital mission, LRO’s seven instruments have been collecting data to find safe future landing sites, locate potential resources for possible human outposts, characterize the radiation environment and test new technology.



STUDENT SHEET #1

Questions and Hypotheses

Did you know often scientists start with a big question in mind before they even have a research question or hypothesis? This often occurs as a result of a very specific, scientific observation, such as the observations you made in the Lunar Image Analysis. These big questions often lead to possible explanations. We call these explanations hypotheses. You may even already have a big question and a hypothesis about your topic! Below you will find a description of what is meant by a “big picture question,” an hypothesis, and a research question.

Big picture questions are the initial questions a scientist will ask while making observations. When researchers observe a feature that is interesting or unique, they will often ask themselves “What is that? How did it form? Why does it appear this way? Or why is this different from other examples?” One of these questions will be the guiding question for the remainder of their research or even possibly their career!

Hypotheses often result from these “big picture questions.” These are in the form of potential answers or explanations for the observation. There can be many working hypotheses which are an attempt to answer the question. Each hypothesis is specific to the data that will be collected. The hypotheses must be testable and falsifiable. This means an answer can be found and the answer can either support or disprove the hypothesis.

Research questions are the best explanations to the big picture questions. Research questions are specific to the data that will be collected. Results from each research question can be pooled together to determine the best answer to the big picture question. Sometimes the hypothesis and research question are considered to be the same.

A few sources that might be useful:

<http://www.lroc.asu.edu/lrolive/#loc=video&category=sci&vid=102>

<http://www.lpi.usra.edu/lunar/moon101>

<http://lroc.sese.asu.edu/news/index.php?/categories/2-Featured-Image>

http://wms.lroc.asu.edu/lroc_browse

<http://lunar.gsfc.nasa.gov/moonfacts.html>

<http://lunar.gsfc.nasa.gov/faq.html>

<http://nssdc.gsfc.nasa.gov/planetary/factseet/moonfact.html>

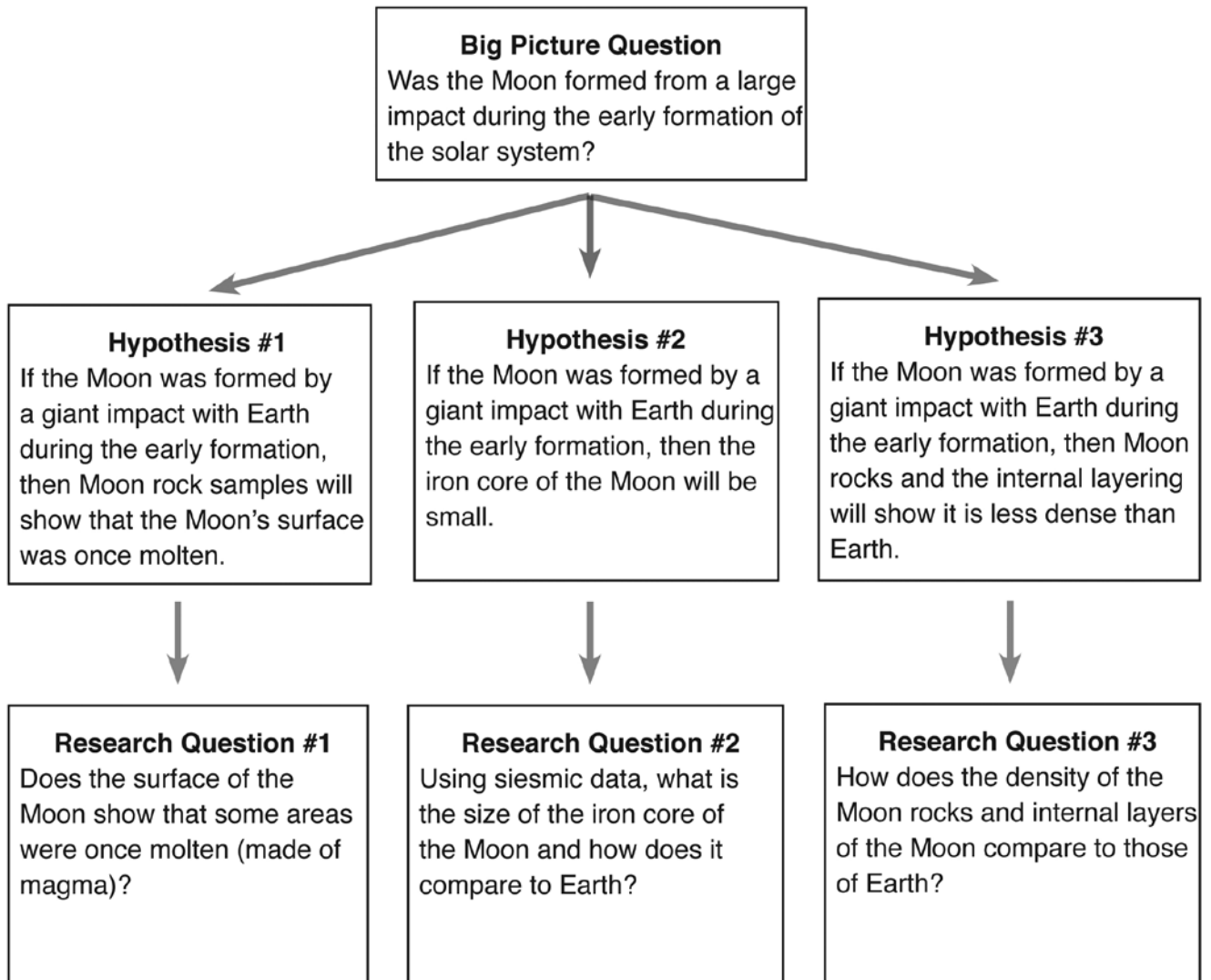
http://www.nasa.gov/multimedia/videogallery/index.html?media_id=135568801



STUDENT SHEET #1

Questions and Hypotheses

Giant Impact Hypothesis Example



STUDENT SHEET #1

Name _____

Questions and Hypotheses

Below you will find 2 examples of stories from real research regarding the Moon. These examples are stories about how the scientists came up with their questions for research. Read through each of these scenarios. Look for the hypothesis and overall research question. The big picture question has been provided for you. Be prepared to share your findings with the class. Don't forget, sometimes the question may not be written in the form of a question, but more as a statement.

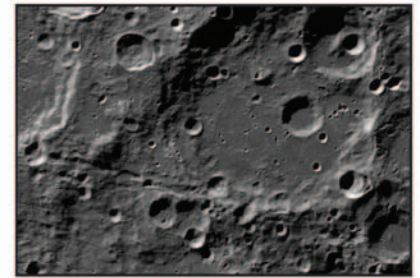
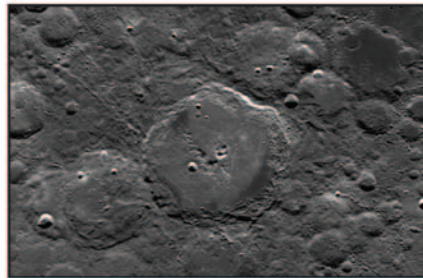
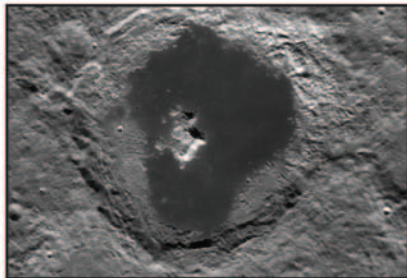
Craters on the Moon

Prior to the 1940's, scientists were fairly certain that craters on the Moon were formed from volcanic activity. Throughout the 1940's into the 1960's, including the Apollo program, scientists studied these craters to uncover if they were volcanic or made by meteor impacts. Lunar Orbiters and the Apollo missions took pictures of the Moon that showed details not seen through telescopes. The Apollo missions also returned rock samples from the Moon. These samples along with better pictures of the craters showed that the craters were the result of impacts and not related to volcanoes.

Big Picture Question: How were craters formed on the Moon?

Hypothesis:

Research Question:



[NASA/GSFC/Arizona State University]

STUDENT SHEET #1

Questions and Hypotheses

Name _____

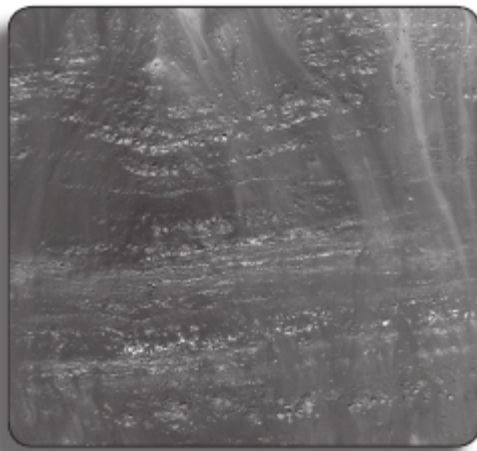
Maria Layers on the Moon:

Scientists first observed layering in the lunar mare (pronounced mahr-ey) when the Apollo 15 astronauts visited Hadley Rille, a channel carved by lava. More recently, images from the LROC camera have shown layering in the mare in the walls of impact craters. The layers average 10-20 m thick and we only see layers in the craters on the mare, not the highlands. Scientists have debated for years about how the mare formed. Was it from a few, very large eruptions or from numerous smaller eruptions? To begin testing this, researchers have been looking for as many examples of layering to identify the range in thicknesses of the mare layer. They will then compare them to chemical data, lava models, and lava flows on Earth to better understand how the mare lavas formed.

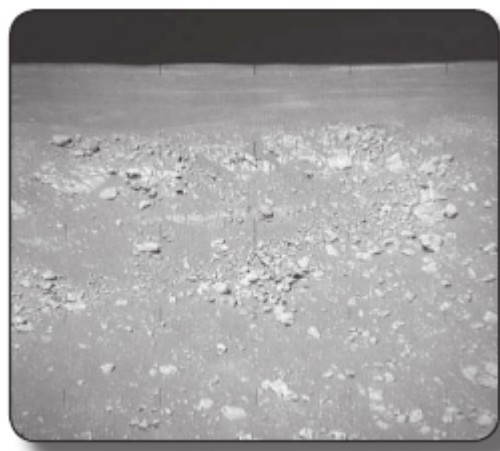
Big Picture Question: How did the maria form?

Hypothesis:

Research Question:



LROC image of Euler Crater layers.
Credit: NASA/GSF/Arizona State University.



Apollo 15 image of Hadley Rill layers.
Credit: NASA/LPI.



STUDENT SHEET #2

Name _____

Identifying the Big Picture Question

For this activity, you will need the observations and your team chosen topic from the Lunar Image Analysis activity. Review the key observations your team used to pick your topic and discuss with your team what was unique and interesting about these observations. Work in a small group to brainstorm some of the big picture questions about your topic. Question prompts have been provided. You are not limited to the number of times you can use a prompt and may not use all of the provided prompts. Additional space has been provided in case you want to use a prompt more than once.

What is _____?

(Should be a specific description of an interesting feature you are unable to identify)

How did _____ form?

(Should be a specific feature)

Why does _____ appear _____?

(A specific feature and a description of the appearance)

Why is _____ different from _____?



STUDENT SHEET #2

Name _____

Identifying the Big Picture Question

Now that you have a list of possible Big Picture Questions, share your favorite one or two with the team. Explain why you are interested in answering this question and what observations were made that brought you to the question.

Top two Big Picture Questions to share:

#1:

This question is interesting and important because:

#2:

This question is interesting and important because:



STUDENT SHEET #3

Name _____

Identifying the Explanations

As a team, you will now need to debate which Big Picture Question you would like to use. Once your team has selected a Big Picture Question, record it here:

Big Picture Question:

With a big picture question in place, you are ready to start brainstorming possible explanations. Below, create a list of possible answers or explanations to the Big Picture Question. Work with your team to create this list.



STUDENT SHEET #3

Name _____

Identifying Explanations with Available Tools

Take some time with your team to see if there are tools available to test your explanations. An explanation cannot become a hypothesis if you do not have the appropriate tools available to test it. In this case, you can use the JMARS for the Moon tool (<http://jmars.asu.edu/download-jmoon>) to see what types of data can be collected. Take a few minutes to use the JMARS for the Moon tool and record the layers that might be helpful in research of your topic. Record those layers below and explain what type of data they can help you research. An example has been provided for you.

| JMARS for Moon | What will be measured or recorded? |
|-----------------------|--|
| example: Lat/Lon Grid | example: measure distances of features in km or find the latitude/longitude of a feature |
| | |
| | |
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STUDENT SHEET #3

Name _____

Identifying the Explanations

With your understanding of what tools you have available, go back to your original brainstorming list and mark the explanations you will be unable to research because you do not have the tools available. From the remaining list, choose two explanations you would like to share with the team as a possible explanation.

#1:

#2:

As a team you will need to debate among all of the possible explanations which is the best. This will be your primary hypothesis. You may pick a second if it is closely related to the primary. We will revisit this hypothesis after writing our research question to ensure it is testable and falsifiable (can prove that it is false).

Primary Hypothesis (DRAFT):



STUDENT SHEET #4

Name _____

Writing a Research Question

In order to write a quality research question, you need to consider the information you need to prove or disprove your explanation (hypothesis). You will need to consider the variables you intend to collect data on. A variable is something that will be measured or observed in an experiment. Below you will find a list to get you started. This list does not contain all of the possible variables, but provides a guide to get you started. Create your own list of variables which are specific to your explanation in the area below.

| Potential Variables | | | |
|--|--|--------------------------------------|---|
| Location | Comparisons | Characteristics | Measurements |
| region distribution near side/far side lowlands/highlands | similarities differences relationships patterns | shape type texture quantity | length diameter circumference height |



STUDENT SHEET #4

Name _____

Writing a Research Question

Using your list on the previous page, create at least 2 questions for your research on the Moon. These questions should be related to your topic/ primary hypothesis and be testable. Once you have written your questions, use the Evaluation Criteria in the box below to see if your question qualifies as a testable research question. If you can put a check (✓) in all of the boxes, your question should be good enough for your team to consider for your research.

Question 1:

Question 2:

| Question | | Evaluation Criteria |
|----------|---|--|
| 1 | 2 | |
| | | Question can be answered using materials available and in the time allotted. |
| | | Question focusses on specific features that can be observed using the LROC WAC Equatorial Mosaic and JMARS for Moon. |
| | | Question does not focus on HOW the feature formed. |
| | | Question includes observations or is similar to one of these: Evidence, shape, similarities, differences, relationship, patterns, etc. |
| | | Question is not a “why” or “how come.” |



STUDENT SHEET #4

Name _____

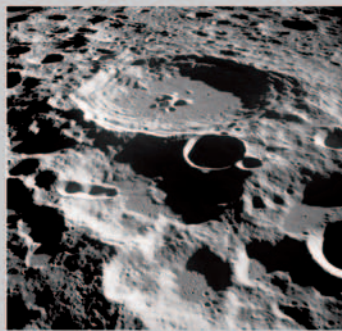
Writing a Research Question

Share your research questions with your team. As a team, debate which question would be the best potential question for your class to research. Decide which final question is the most interesting and answerable question using LROC images.

Try not to feel “possessive” of your own created question. Your creation and participation in team discussions and decisions will help to select the best and most interesting question to focus on for your research.

Why is this question the best? List the reasons here:

Final Science Question:



Credit: NASA



STUDENT SHEET #5

Name _____

Writing a Testable Hypothesis

Refer to your primary hypothesis written in Student Sheet #3 and your newly written team question. You will need to modify the hypothesis to more accurately reflect the research question your team has chosen. Once you have written your hypothesis, use the Evaluation Criteria in the box below to see if your hypothesis qualifies as a testable and falsifiable hypothesis. If you can put a check (✓) in all of the boxes, your hypothesis should be good enough for your team to consider for your research.

Primary Hypothesis Draft:

Research Question:

Research Hypothesis:

| (✓) | Evaluation Criteria |
|-----|--|
| | Hypothesis can be answered using materials available and in the time allotted. |
| | Hypothesis focuses on specific features that can be observed using the LROC WAC Equatorial Mosaic and JMARS for Moon. |
| | Results of the experiment could support the hypothesis OR disprove it. |
| | Hypothesis includes observations or is similar to one of these: evidence, shape, similarities, differences, relationship, patterns, etc. |
| | Hypothesis includes an 'If....then...' statement (*note* not always 100% true. This works MOST of the time.) |



STUDENT SHEET #5

Name _____

Writing a Testable Hypothesis

If it meets the criteria, share your hypothesis with your team. As a team, debate which hypothesis would be the best for your class to research. Decide which hypothesis is the most interesting and answerable question using LROC images.

Try not to feel "possessive" of your own created hypothesis. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting hypothesis to focus on for your research.

Why is this hypothesis the best? List the reasons here:

Final Science Question:**Final Science Hypothesis:**

SUPPLEMENTAL IMAGES/ MATERIALS/ RESOURCES:

Sample Answers:

STUDENT SHEET #1

Questions and Hypotheses

Below you will find 2 examples of stories from real research regarding the Moon. These examples are stories about how the scientists came up with their questions for research. Read through each of these scenarios. Look for the hypothesis and overall research question. The big picture question has been provided for you. Be prepared to share your findings with the class. Don't forget, sometimes the question may not be written in the form of a question, but more as a statement.

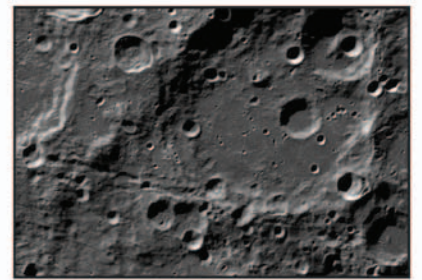
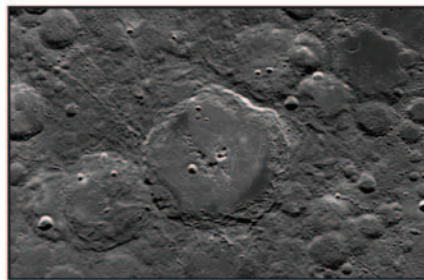
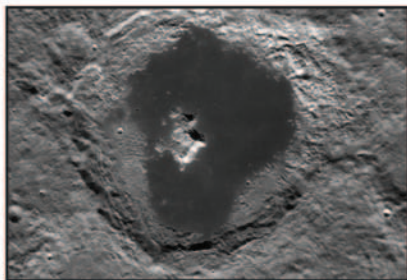
Craters on the Moon

Prior to the 1940's, scientists were fairly certain that craters on the Moon were formed from volcanic activity. Throughout the 1940's into the 1960's, including the Apollo program, scientists studied these craters to uncover if they were volcanic or made by meteor impacts. Lunar Orbiters and the Apollo missions took pictures of the Moon that showed details not seen through telescopes. The Apollo missions also returned rock samples from the Moon. These samples along with better pictures of the craters showed that the craters were the result of impacts and not related to volcanoes.

Big Picture Question: How were craters formed on the Moon?

Hypothesis: **If craters on the Moon were formed by volcanoes, then the rock around the crater will be volcanic.**

Research Question: **Were the craters on the Moon formed from volcanoes or from meteor impacts?**



[NASA/GSFC/Arizona State University]

Sample Answers

STUDENT SHEET #1

Questions and Hypotheses

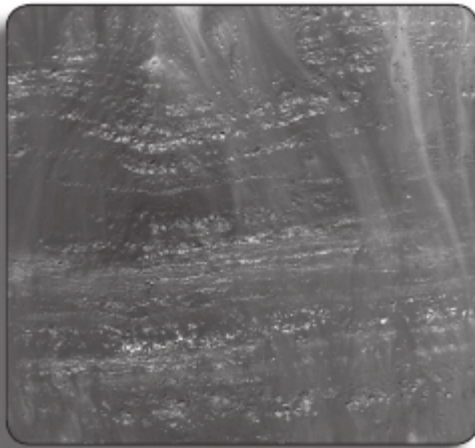
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Big Picture Question: How did the maria form?

Hypothesis: **The mare were formed from many small eruptions over a long period of time.**

Research Question: **Did the mare on the Moon form from many small eruptions over a long period of time, or from a few, larger eruptions in a short period of time?**



LROC image of Euler Crater layers.
Credit: NASA/GSF/Arizona State University.



Apollo 15 image of Hadley Rille layers.
Credit: NASA/LPI.

Rubric

The following table has been developed to explain the rationale behind the evaluation criteria. The rationale may be helpful in your explanations to students regarding high quality research questions.

| Evaluation Criteria | Rationale |
|---|--|
| Question can be answered using materials available and in the time allotted. | Focus on questions that can be answered using an image. Consider the amount of data that will be necessary to answer the question. For example, global questions are very time consuming and many scientists will spend their career collecting this kind of data. |
| Question focuses on specific features that can be found using the LROC WAC Equatorial Mosaic. | Not all questions can be answered by a picture. If students ask a question that would require video or a direct presence to observe, then it is typically not investigable by looking at an image. |
| Question does not focus on HOW the feature formed. | These are often the big picture questions we are trying to answer. We want to know if the processes are the same or different from those we see on Earth, therefore we look for evidence (variables) that then tells us how the features are formed. |
| Question includes one of the following words: evidence, shape, similarities, differences, relationships, patterns, etc. | This is a small list, but covers many of the general terms students could use in their question. These are directly related to evidence they could collect. Students just need to plug the variables in. |